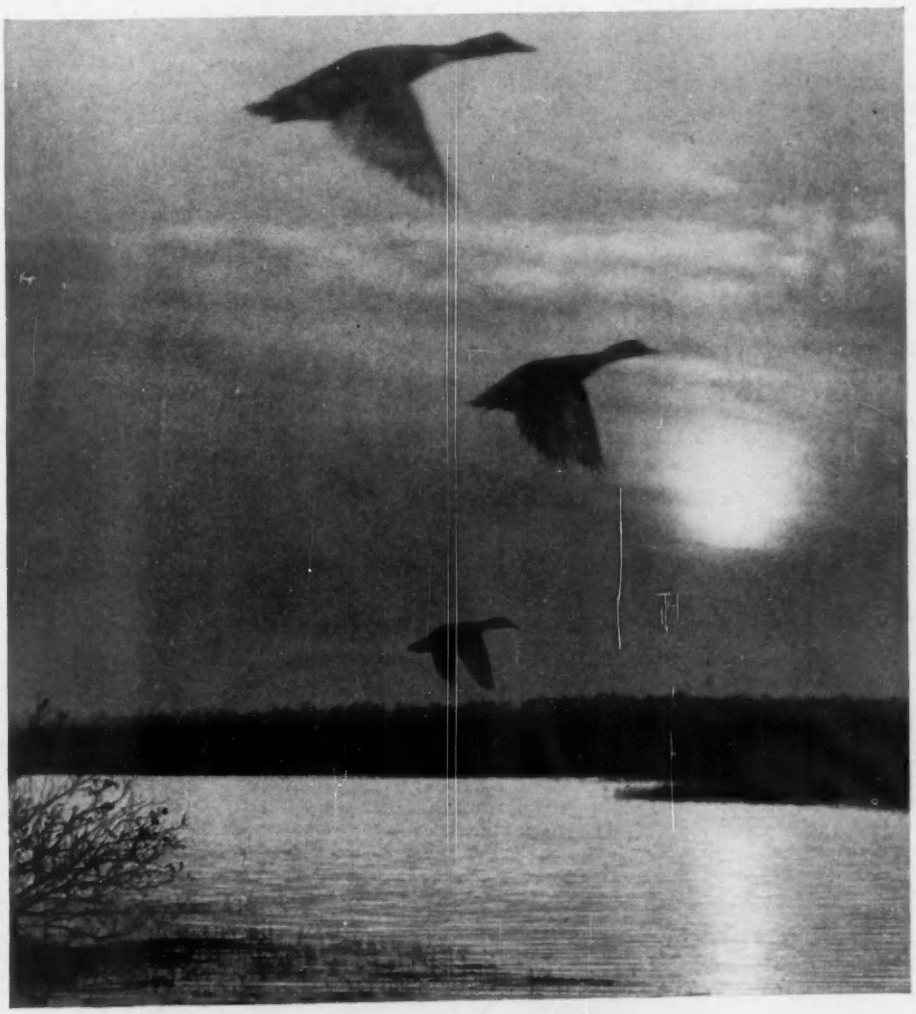
THE TECH ENGINEERING NEWS



MARCH, 1933 VOLUME XIV, NO. 2
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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THE TECH ENGINEERING NEWS

THE PROFESSIONAL JOURNAL OF THE UNDERGRADUATES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

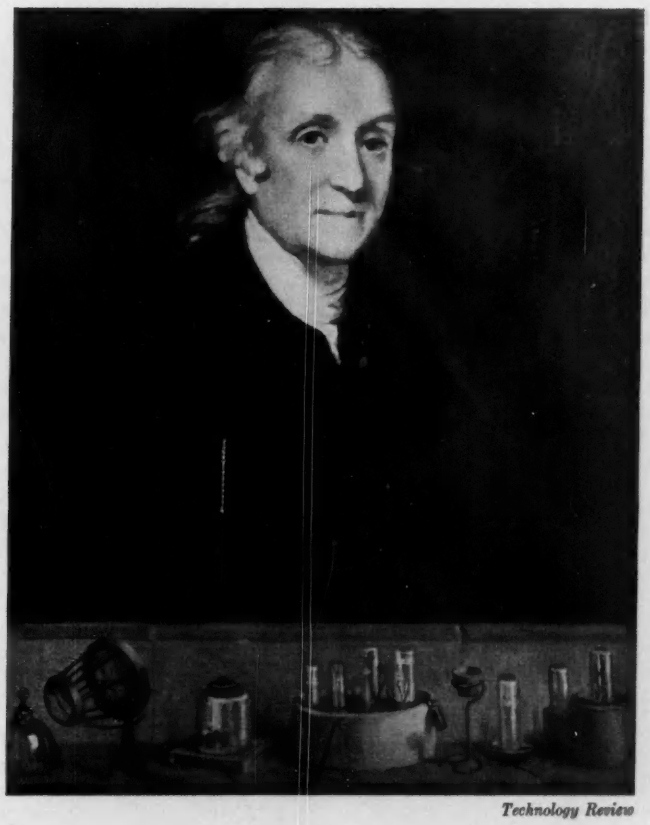
VOLUME XIV MARCH, 1933 NUMBER 2

The Theories of JOSEPH PRIESTLEY *—the Firebrand Philosopher*

By TENNEY L. DAVIS

Associate Professor of Organic Chemistry
Massachusetts Institute of Technology

THE debt of American chemists to Joseph Priestley is far greater than the debt which every chemist in the world owes to the discoverer of oxygen. Priestley settled in this country in 1794, at the height of his fame, and his presence here proved to be an enormous stimulus to scientific discussion and experimentation. Indeed modern chemistry in this country may be said to have begun with Priestley. A group of chemists, meeting at the Priestley home at Northumberland, Pennsylvania, in August, 1874, to celebrate the centenary of the discovery of oxygen, found inspiration there which two years later led to the founding of the American Chemical Society.



Technology Review

Joseph Priestley was a dissenting English clergyman who dabbled in chemistry for his own amusement. His interest in gases perhaps started and was certainly nourished by his observations on the gas from the fermentation vats of a brewery near his home in Birmingham. He invented the pneumatic trough for collecting gases over water or mercury and discovered, in addition to oxygen, various other gases, nitric oxide, nitrous oxide, hydrogen chloride, ammonia, sulfur dioxide, silicon fluoride, and carbon monoxide. He recognized the similarity between combustion and respiration, observed that green plants in the sunlight produce oxygen, invented soda water, and wrote voluminously on political and theological subjects. He also wrote an English grammar which was widely used in the elementary schools.

His "Experiments and Observations in Different Kinds of Air," published between 1774 and 1786, is written inthe beautiful English which is characteristic of all that he wrote. It is still interesting and entertaining to read, for he digresses and philosophizes and gives the reader an insight into the workings of his mind. His humor as well as his modesty is evident in many places. He even ascribes his discovery of oxygen to the chance which led him to try the effect of the gas on the flame of a burning candle.

"I cannot, at this distance of time, recollect what it was that I had in view in making the experiment; but I know I had no expectation of the real issue of it. Having acquired a considerable degree of readiness in making experiments of this kind, a very slight and evanescent motive would be sufficient to induce me to do it. If, however, I had not happened, for some other purpose, to have a lighted candle before me, I should probably never have made the trial; and the whole train of my future experiments relating to this kind of air might have been prevented. . . .

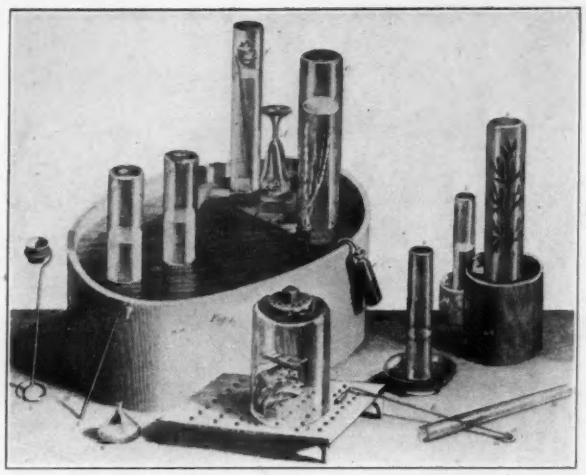
"From the greater strength and vivacity of the flame of the candle, in this pure air, it may be conjectured, that it might be particularly salutary to the lungs in certain morbid cases, when the common air would not be sufficient to carry off the phlogistic putrid effluvium fast enough. But, perhaps, we may also infer from these experiments, that though pure dephlogisticated

air (oxygen) might be very useful as a *medicine*, it might not be so proper for us in the usual healthy state of the body: for, as the candle burns out much faster in dephlogisticated than in common air, so we might, as may be said, *live out too fast*, and the animal powers be too soon exhausted in this pure kind of air. A moralist, at least, may say, that the air which nature has provided for us is as good as we deserve.

"My reader will not wonder, that, after having ascertained the superior goodness of dephlogisticated air by mice living in it, and the other tests above mentioned, I should have the curiosity to taste it myself. I have gratified that curiosity, by breathing it, drawing it through a glass-syphon, and, by this means, I reduced a large jar full of it to the standard of common air. The feeling of it in my lungs was not sensibly different from that of common air; but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that, in time, this pure air may become a fashionable article of luxury. Hitherto only two mice and myself have had the privilege of breathing it."

Priestley regarded his mice as expendable apparatus, but as apparatus to be handled with care and to be conserved if possible. "For the purpose of these experiments it is most convenient to catch the mice in small wire traps, out of which it is easy to take them, and holding them by the back of the neck, to pass them through the water into the vessel which contains the air. If I expect that the mouse will live a considerable time, I take care to put into the vessel something on which it may conveniently sit, out of reach of the water. If the air be good, the mouse will soon be perfectly at its ease, having suffered nothing by its passing through the water. If the air be supposed to be noxious, it will be proper (if the operator be desirous of preserving the mice for further use) to keep hold of their tails, that they may be withdrawn as soon as they begin to show signs of uneasiness; but if the air be thoroughly noxious, and the mouse happens to get a full inspiration, it will be impossible to do this before it will be absolutely irrecoverable."

Priestley's attachment to the chemical doctrine which supposed the real existence of a fiery principle, phlogiston, and the vigor with which he expressed and defended his political and theological opinions are both



Journal of Chemical Education

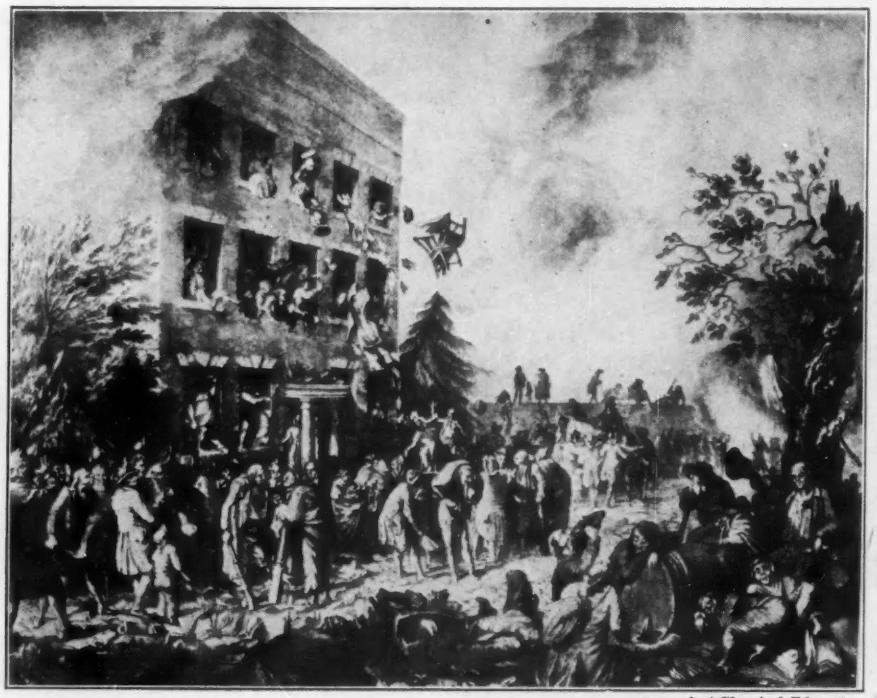
Priestley's apparatus for collecting gases over water and for studying their properties.

indicated by the epithet of "firebrand philosopher" which was applied to him. He favored the American colonists in their war for independence, and he favored the patriots of the French Revolution. Burke repeatedly inveighed against his character in the House of Commons. When the French made him a citizen of their country and a member of their assembly, his position in England was further damaged. As a dissenter, he advocated complete religious freedom. He was an open enemy of all religious establishments, in particular of the Church of England, and he would not suppress his inclination toward controversy for the sake of popular opinion. The feeling against him culminated in the Birmingham riots of 1791, on the day of the anniversary of the French Revolution. The meeting house in which he preached was burned, his own house and houses of several of his friends received the same treatment, his library and apparatus, and the manuscripts upon which he had been engaged for many years were destroyed. He escaped to London in a mail coach under a borrowed name. Here his colleagues of the Royal Society refused to admit him to their meetings. His sons had emigrated to America, and in 1794 he followed their example.

Priestley was welcomed hospitably on his arrival at New York, but soon proceeded to Philadelphia, which was then the capital city of the United States, and shortly thereafter, having refused an offer of the professorship of chemistry in the University of Pennsylvania, he definitely settled at Northumberland, Pennsylvania, where he built a house, installed his library and laboratory, and resumed his theological writing and chemical experimentation. He came to Philadelphia occasionally to preach in the Unitarian Church or to attend meetings of the American Philosophical Society of which he became a member. He died at Northumberland February 6, 1804, and is buried there.

Priestley had been a friend and frequent correspondent of Franklin. In America he made the acquaintance of Washington, whose religious views he liberalized, and of Jefferson with whom he was entirely in accord. He found scientific companionship in such men as

(*Continued on page 37*)



Journal of Chemical Education

Old print showing the destruction of Priestley's house and laboratory during the Birmingham riot, July 14, 1791.

OXYGEN: FRIEND AND FOE

By LEROY F. MAREK

Assistant Professor of Chemical Engineering
Massachusetts Institute of Technology

THE element, oxygen, atomic weight 16.0000, occupies a unique position in the world's affairs. About 50 per cent by weight of the earth's crust is oxygen; 20.8 per cent by volume of the atmosphere is oxygen; 88.80 per cent by weight of water is oxygen; 53.1 per cent by weight of silica sand is oxygen; about 60 per cent by weight of the human body is oxygen; and so on. It is an important constituent of sugar, starch, wood, cotton, glass, porcelain, soap, shoe polish, rouge, tooth paste, cement, bricks, paint, varnish, lacquer, floor wax, sulfuric acid, caustic soda, etc., etc., ad infinitum. Indeed, it is so all-pervading that people normally take little account of its presence or its import.

But oxygen is important not merely because of its preponderance on the earth. It is quite versatile in its accomplishments, particularly when the accomplishments are eyed with the view of their effect upon human life. It is true that these feats are all based upon the same chemical property, but the degree and order of application of the property may so warp and bend the result that all semblance of relationship is lost. Thus, to most people the gentle, beneficent, beautifully controlled combustion processes occurring in the body bear no relation to the fierce and destructive tongues of flame that consume a burning building. And yet both processes are the result of the same tremendous desire of oxygen to combine chemically with other substances. Likewise, the uncontrolled degrading effects of oxidation manifest in such events as the spontaneous combustion of haystacks, the reversion of metals to the state of an ore, the deterioration of rubber goods, the destruction of paint and lacquer films, etc. bear little outward resemblance to the controlled, though, from the energy standpoint, still degrading, processes of oxidation used in the arts and industries for man's good.

It is of interest to examine some of the effects produced by this remarkable element and to glimpse a narrow view of its potency in the cosmology of the earth.

The green plants of the earth constitute an enormous chemical factory busy with the synthesis of large stores of numerous organic substances, many of which are very complex in structure. The energy necessary for this synthesis work comes from the sun; the raw materials from the earth and air. Man has a very large interest in this work of the plants for it makes available to him the food necessary for his growth and the fuel necessary for his energy supply. Thus, while plant-foods are quite elementary, consisting of mineral salts, water, and carbon dioxide, animal-foods are very complex, consisting principally of material derived either directly or indirectly from living matter. Indeed, relative to the plants, animals in general have a very poorly equipped factory for chemical synthesis. Animals do accomplish certain synthesis, but not on a comparative scale with the plants, and without the storage of large amounts of energy.

The major chemical reactions which occur in animal life are the reverse of those taking place in plant life and constitute, principally, destructive oxidation reactions. These oxidation reactions result in the release of energy previously stored up by plants, which is used in various ways. Part of it furnishes heat to keep the body warm; part is used up in mechanical motion; part furnishes the impulse needed for cell building; and in some mysterious way, part gives "life" to an otherwise complex but inert mass of chemicals.

The energizing of man, therefore, results from the use of energy which has been derived from the sun, bound up by the plants, and released through the action of oxygen in his own body. Through this action of oxygen on foodstuffs, carbon dioxide is formed. This is exhaled to the atmosphere where it is again available to the plant life chemical factory for conversion into sugars, starches, cellulose, and the myriad of other compounds that go to make up the trees, shrubs, and other "green" life. The turmoil of life upon the earth represents, then, a tiny fraction of the solar outpourings.

These processes go on automatically without thought on the part of man, and except that attention is sometimes needed in the case of his own distress, receive little notice from the average person. There are other oxidation reactions, likewise automatic in that they do not

(*Continued on page 38*)

Uncontrolled oxidation: burning naval stores.

United States Naval Institute Proceedings

SURVEYING THE UNIVERSE

—*Applications of Physical Research to Stellar Magnitudes*

By L. B. ANDREWS
Executive Secretary
Harvard Observatory

THERE are two questions that immediately assume oral form the moment a non-astronomer meets an astronomer: How can an astronomer predict years in advance the exact moment an eclipse of the sun is to occur and where one must go in order to see it? And how in the world do you know all these things about the distances, diameters, temperatures, and what not of the stars? In this story an attempt will be made to answer the latter question, though the former is really much the simpler. The resulting story will show how closely the astronomer is a kin of the physicist, applying the methods and results of physical research to tantalizing celestial problems.

The engineer learns at an early age to determine large distances with high precision. Given the problem of surveying the distance from one mountain peak to another, he proceeds by the simple process of triangulation, for which one of the essentials is an accurate baseline. For stellar distances the surveyor's terrestrial baseline of a few hundred feet, or even a baseline in length equal to the diameter of the earth, 8,000 miles, is completely insignificant. In fact, even the latter baseline suffices to determine the distances of a few bodies only — the moon and two or three asteroids which approach periodically within a few million miles of the earth. The determination of the distances of the stars requires a baseline the diameter of the earth's orbit about the sun — a matter of 185,000,000 miles. One observes the position of the star, whose distance is sought, with respect to the fainter and presumably more distant stars at intervals of six months, when the earth will be on opposite sides of its orbit, and even with this apparently tremendous baseline the shift in the position of the star nearest to our sun is only 1.5 inches. Photographic measurements of this parallactic shift have advanced, however, to such a degree of precision that a displacement in position in excess of 0.01 inch may be measured with reasonable accuracy. If one cares to compute the distances of the nearest and most distant stars whose parallaxes may thus be measured, one will find answers of 26 trillion and 2 quadrillion miles respectively. Or to use a picturesque and understandable unit, the light-year, the distance light travels in one year, the light from the nearest star has required about 4.3 years for its journey earthward, while the most distant star, whose parallax is directly measurable, is close to 300 light-years away. When one remembers that astronomers of today speak of distances of hundreds of thousands and millions of light-years, it appears that these measurements have just scratched the surface.

The determination of larger distances rests upon considerations of the real and apparent brightnesses of the stars. If one knew how bright a star really would be if placed at a known distance from us, one could from the observation of its brightness, as one actually observes it, derive its distance, inasmuch as the intensity of its light will decrease inversely as the square of its distance. Astronomers measure stellar brightness in terms of magnitudes, a term handed down from ancient Greece, whereby the brightest stars in the sky are of the first magnitude and the faintest stars visible to the naked eye are sixth magnitude stars. When the accurate photometry of stellar magnitudes became possible, it was discovered that this five-magnitude interval represented a hundredfold change in brightness, or a change of one magnitude represented a change of two and one-half times in brightness. On this basis the scale of magnitudes has been extended, on the one hand, to the telescopic stars of which the largest telescope, the 100-inch reflector on Mt. Wilson, will show stars of the twentieth magnitude and, on the other hand, to the sun whose magnitude is -27. The luminosity of a star thus observed is called its apparent magnitude. The luminosity the star would assume if placed at a distance of 33 light years is called its absolute magnitude.

The apparent magnitude of a star will depend on three factors, the distance of the star, its size, and its temperature. For those stars whose distances are known from parallactic measurements, the distance effect may be eliminated and absolute magnitude determined. Any dispersion in absolute brightnesses will then be the result of the two remaining factors. One might investigate, first off, the temperatures of the stars. If a star behaves like a terrestrial body, the color of the star should be a criterion of its temperature. A red star should be relatively cool, a yellow star somewhat hotter, while white, blue-white and blue stars should follow in order of increasing temperature. Visually the stars may be seen to vary in color, but the actual determination of their colors must be placed on a scientific basis; eye estimates would be too inaccurate. The photographic

The Small Magellanic Cloud, one of the nearest galaxies.

Model of a proposed 200-inch telescope.

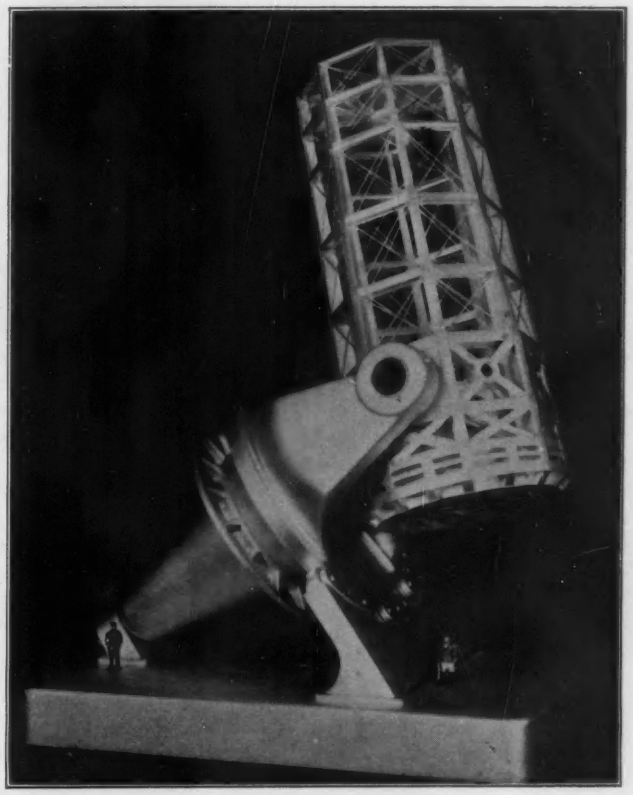
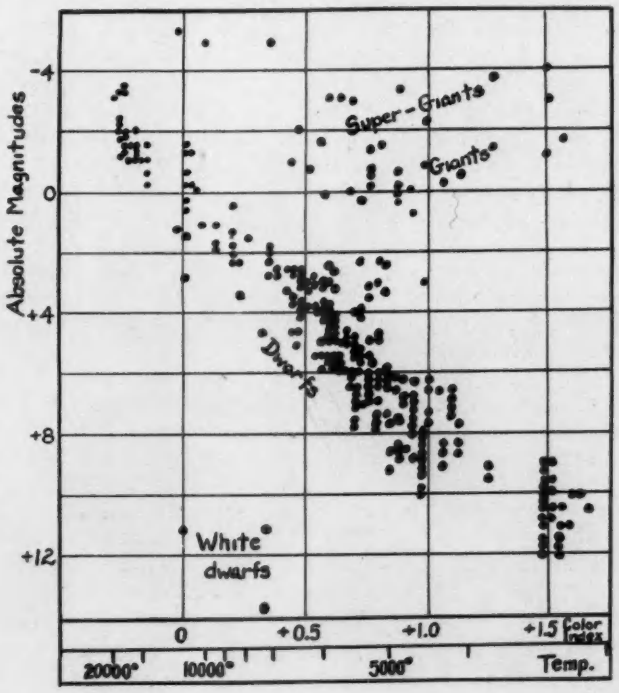


plate has been to the present the best source of color determination. By registering on a photographic plate by means of appropriate color filters, firstly, an image of the star resulting only from the blue and violet portion of its light and secondly, an image resulting only from the yellow portion of its light, one obtains respectively so-called photographic and photo-visual magnitudes. A star rich in blue light and poor in yellow will be bright photographically and weak photo-visually, whereas a star of the reverse characteristics will register in the reverse fashion. The difference of the two magnitudes thus obtained will indicate the color of the star. This difference is called the color-index of the star and ranges from about -0.3 for the bluest stars to $+2.0$ for the reddest stars.

That the color-index of a star is correlated with its temperature is adequately confirmed by spectroscopic measurements of temperature. Planck's investigation of the radiation from black bodies led to a mathematical equation expressing the intensity of emission of various colors by bodies at various temperatures. Thus a body at 2000° C. will emit reds with great intensity and yellows, greens, and blues with ever decreasing intensity, while a body at a temperature of 30,000° C. will emit blues with great intensity and reds almost negligibly. It is quite apparent that as a result of these differences in emissions, the color-indices will correlate very nicely with the actual temperatures, which range from about 3000° C. for the surface temperature of the reddest stars to 30,000° C. for the blue-white stars, while temperatures of the order of 80,000° C. have been suggested for some exceptional stars. Any study of the internal conditions of a star will show that the temperature near the center of a star must be of the order of millions of degrees.

Suppose that having determined the colors of all those stars for which absolute magnitude can be computed, one distributes them into compartments according to their color-indices. Any dispersion in absolute magnitude must now be the result of difference in size. The results of such a sorting are most interestingly displayed in the accompanying diagram. If the separation of the stars into two branches as shown is due to size, then those stars of a given color-index that fall on the branch of high intrinsic luminosity must be larger than those falling on the branch of low intrinsic luminosity. To the former has been given the name "giants," to the latter "dwarfs." It is noticeable that the distinction apparently ceases for stars hotter than 8000° C. Whether this apparently correct deduction is valid or not depends upon the direct instrumental measurement of the diameters of a few sample stars.



Plot of stars arranged according to absolute magnitude.

The stars are, of course, so far away that even the largest telescopes and the highest possible magnification still will not show them as discs, so that direct measurement of size is impossible. Fortunately an instrumental device exists that will measure these diameters, the Michelson interferometer. The application of the interferometer to precision measurements in physical laboratories is familiar to all who follow modern physical practice. It serves in general to determine the distances between nearly coincident sources of light with great accuracy. Thus in astronomy the distance between two stars so close together that telescopically they are inseparable might be accurately determined; not their linear separation, of course, but their angular separation. As a matter of fact the earliest application of the interferometer in astronomy was to just that problem. In measuring the angular diameter of a star, the case is theoretically analogous to that of measuring the angular separation of two adjacent stars. Here the two sources of light are the two halves of the star formed when one imagines it to be bisected. The interferometer measures the angular separation of two mean points representative of the two halves. The relation between this angle and the true angular diameter of the star may be deduced theoretically. This instrument has been successfully applied to a few of the brighter and nearer stars and linear diameters derived. For example, Antares, a red

(*Continued on page 39*)

ICE, SNOW, AND SCIENCE
—*Meteorological Research on Mt. Washington*

By ***LOUIS C. SMITH '36***

ON the summit of frigid Mt. Washington, where the wind has been known to blow with a velocity of nearly two hundred miles an hour, three young men are spending the winter to make scientific investigations. Weather, aurora, radio, and solar radiation observations are being made as an important part of the program arranged by the International Polar Year Commission, which includes some of the leading scientists of the world, under the direction of Dr. laCour of Denmark. The polar year program is an international project for which the leading nations of the world have built stations in the polar regions to probe the variable quantities of nature. The United States has appropriated funds for stations at Point Barrow and Fairbanks, Alaska, but has made no appropriation for the Mt. Washington Observatory.

This station is a private enterprise made possible by generous gifts of instruments, supplies, and money by scientists, scientific societies and companies. The layout on the summit consists primarily of a fully equipped meteorological station and the special instruments required for the polar year work. The observers on the mountain are Robert Monahan, Salvatore Pagliuca, and Alexander McKenzie. Joseph Dodge, hut manager of the Appalachian Club, is directly in charge of the expedition and will run the Pinkham Notch station. These men are receiving no remuneration for their efforts beyond that of the useful experience and training they are acquiring. Auxiliary observations to check those taken on the summit will be made at Pinkham Notch, which is about two and one-half miles away in a straight line, but four thousand feet lower in altitude.

Reading a pyrheliometer. Note the extensive frost work built out in the direction of the prevailing wind.

One of the important objects of the party is to measure the amount of wind which passes in a day. To do this, use is made of a portable anemometer consisting of copper cups mounted on a vertical ring which will be revolved by the wind, the number of revolutions being counted by a system of gears. The winds on Mt. Washington are impregnated with a fine mist which forms a very thick coating of frost on anything that lies in their path. Since it was found that the formation of this frost soon stopped the anemometer, an ingenious heating element was devised. This is designed to melt the frost as soon as it forms. The velocity and surface direction of the wind are being measured every three hours with a precision in the latter measurement of about five degrees.

To measure the velocity of the wind during short intervals of time, such as in storms, the weather experts on Mt. Washington are using a special form of anemometer which is designed to give a direct reading of the speed of the wind. It was directly calibrated for wind velocities up to ninety miles per hour in the huge wind tunnel in the Guggenheim Research Laboratories at Massachusetts Institute of Technology. Although the winds on Mt. Washington will occasionally exceed this velocity, the calibration was the maximum possible in the wind tunnel.

Plotting the direction of the upper air currents is one of the featured investigations, both of the polar year program and of the Mt. Washington Observatory. Very little is known about the upper air currents, except that they are variable and follow a definite pressure cycle. Cyclones are believed to have their origin in them. A cyclone in the meteorological sense is a system of winds which circulate about an area of relatively low barometric pressure and blow spirally inward. The plotting is done by releasing standard balloons filled with hydrogen gas which rise with a standard rate of ascent. Their progress is followed with a theodolite which gives their direction and angular elevation from the origin at any time. These values are immediately put down on the plotting board and later a graphic picture of the balloon "run" is made for further study. These balloons are of different colors for differently colored skies and may rise to a height of thirty thousand feet before bursting. The Polar Year Commission has designated certain times at which the balloon runs are to be made simultaneously at all stations coöperating in the work. Since this time falls at night in this country, special candles, protected by a cover, have been fastened to some of the balloons for use at night. These runs are graphed with particular care, since the commission will collect and use them for research. As a result of this work scientists will probably reach a definite conclusion as to the properties of the upper air currents and the formation of cyclones in them.

Since the ridges and valleys of the White Mountains are oddly orientated, the winds which blow over Mt. Washington display many peculiar characteristics. It is frequently observed in plotting the balloon runs that the balloons at times descend instead of rising because the air currents are rushing down with a speed greater than that of the balloon upwards. One day last fall the wind was blowing with a speed of ninety miles per hour from the east at the summit, and at the same time at Pinkham Notch it was blowing from the west with the same velocity.

A northwest wind in approaching Mt. Washington

passes through a funnel-shaped valley which, according to the laws of aerodynamics, would account for its high velocity.

Frost formations, referred to in a previous paragraph, have reached a length of three or four feet, and the party on the summit is planning to study this remarkable growth in some detail. Dr. H. C. Willett, of the Massachusetts Institute of Technology, is interested in their formation since their amorphous structure indicates that even at the lowest temperatures prevailing at these high levels the clouds consist of super-cooled water droplets rather than ice crystals.

The expedition will measure the solar radiation, in accordance with the polar year program, by means of a pyrheliometer or solar ray bulb. This is a very sensitive and delicate instrument and must be carefully protected when in use. It consists of a sphere of soda-lime glass in which are two concentric silver rings connected by a thermopile of fifty hot and fifty cold junctions. The inner ring is black and absorbs the solar radiation; the outer ring is white and reflects it. The difference in temperature creates a small electromotive force which is recorded in calibrated form on a chart driven by clock work. On a clear day the curve is fairly regular and reaches its maximum intensity about 11:15 in the morning. Clouds vary the chart curve and record for a later study the character of the sky and the intensity of the sun's rays.

With a camera loaned by Harvard University, the Mt. Washington Observatory is photographing the meteor showers as they occur. For their auroral observations they are using a laCour starbox, a lighted chart of the heavens which permits the observer to determine the positions of the Northern Lights and their streamers by their reflections upon it. With this information, the observers can plot the arcs of the aurora. They are conforming with the plans of the Polar Year Commission by making routine measurements of the temperature and atmospheric pressure every three hours as well as by determining the relative humidity, cloud formation, and precipitation. For the latter measurement, Dr. C. F. Brooks of the Blue Hill Observatory has invented a special form of snow gauge with its troughs parallel to the sides of the mountain in order to get a true catch. However, since there is so much wind-driven snow, it is impossible to measure accurately the precipitation at the summit. This reading is made at the Pinkham Notch station.

Recent reports from the mountain top indicate that even on Mt. Washington the winters are becoming less severe. For instance, the January mean temperature was 12.6 degrees which is higher than any January average recorded from 1871–1887, except the one year of 1880. (During the period from 1871–1887 the government maintained a winter meteorological station on Mt. Washington.) February temperatures are running true to form, however, for on February 8 the temperature dropped to the winter's minimum of −29 degrees, a fall of 56 degrees in twelve hours. An interesting phenomenon accompanying this change was a spectacular display of blue sparks by the wind vane which had become charged with static electricity.

Following the ascent of a pilot balloon with a theodolite.

Extensive research is being carried out at the station in the field of radio. Studies will be made of the erratic action of the Kennelly-Heaviside layer and the propagation of waves of medium and ultra-high frequencies. The Kennelly-Heaviside layer is an ionized region above the earth's surface which reflects the radio waves downward. The party is studying the inconsistent properties of this layer which causes the "fading out" of radio signals.

As in many modern projects, radio communication will play its part in the work of the expedition. A radiotelephone, operating on a wavelength of seven meters, has been installed for communication between the Pinkham Notch station and the summit. This latter device is still in the experimental stage and will operate only when the receiver is visible from the transmitter. It will prove invaluable in permitting the free exchange of data between the two stations. There is also the usual type of short-wave transmitter with the call letters, W1OB, which operates on amateur frequencies. Albert McKenzie, the radio operator, sends daily weather reports to Mr. Albert Sise of Brookline, Massachusetts, who is in charge of the Boston relay station. Mr. Sise telephones these reports to the Boston office of the Weather Bureau, to the Blue Hill Observatory of Harvard University, and to the meteorological department of the Massachusetts Institute of Technology. The polar year stations throughout the North also keep in touch with one another and compare their incomplete results by means of radio.

This modern expedition is very different from that of the Weather Bureau years ago, which suffered great privations because of inadequate shelter. In contrast, the present party is comfortable even when severe storms isolate it for days at a time.

Cloud formations flowing over the southern peaks of the Presidential Range.

Modern Magic in
THE DIAL TELEPHONE SYSTEM
—A Glimpse Behind the Scenes

By ***GORDON K. BURNS '34***

YOU need a doctor in a hurry; or you wish to order a load of lumber from a dealer in the next town; or you want to find out what play is on at the Majestic. So you look up the telephone number in the directory — let us suppose it turns out to be HANcock 1234 — and then you reach for your dial telephone. A few quick twists of the wrist as you spell out H-A-N-1-2-3-4, a brief pause, and straightway you are talking with the desired party. Simple, is it not? But did you ever stop to think of what happens behind the scenes, within the walls of central office buildings, when you use your dial telephone?

It will be easier to understand the workings of the dial system if first we see what is required of *any* telephone system. Briefly stated, the situation is as follows: Wires from all the telephones in your town (or section of your city) converge to a common "central office" and terminate there. The job of the central office is simply to provide, upon demand, temporary connections between these "subscribers' lines," so that any subscriber can talk with any other subscriber in town.

But how are long-distance connections made? To see the answer to this question, let us take a bird's-eye view of the nation's telephone system. Thousands of central offices dot the map, each being the nucleus for ten thousand (or less) subscribers' lines. The offices themselves are interconnected by a web of "trunk" lines. When you call a subscriber in another city, your own office forwards the call to the proper office on one of these trunks, and it is there put through to the called party.

Fundamentally, then, the principle of central offices and trunks is simple enough; but the circuits and apparatus which are required in putting the theory into practice make telephone communication a fascinating subject indeed. Until a few years ago, for example, human fingers routed every telephone call through every step of its journey. Although this "manual system" is now slowly giving way to the dial system, it is by no means obsolete. Machine switching will be a good deal easier to understand, if first we briefly examine the manual system.

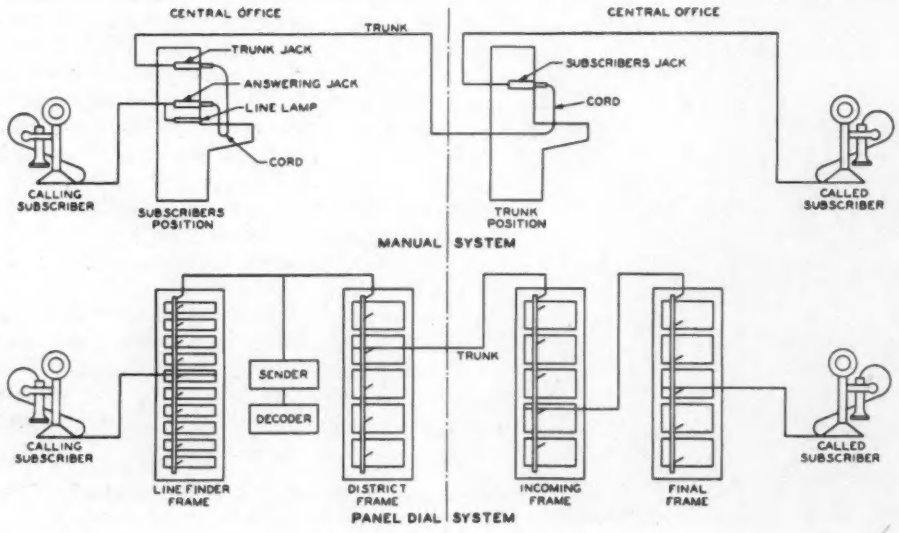
In a manual office the subscribers' lines all terminate on a long bank of "jacks" or sockets. This bank is divided up in "subscribers' positions," with an operator at each position. Each subscriber's line is connected to an "answering jack" at *one* of these positions, and to a "multiple jack" at *every* position. When a subscriber takes his receiver off the hook, a lamp glows just below his answering jack, and the operator at that position plugs one end of a cord into the aforesaid jack. Upon being told what number is wanted, she plugs the other end of the cord into the called subscriber's multiple jack at her position, and the connection is complete. Associated with this double-ended cord is certain other equipment, including a battery supply, a ringing and listening key, and the operator's telephone headset, but its principal function, so far as we are concerned, is to link the two subscribers together.

Another set of jacks in the subscribers' position is connected, not to subscribers' lines, but to trunks running to other central offices, where they terminate in "trunk positions." When a calling subscriber asks the operator for another office, she plugs the free end of the double-ended cord into one of *these* jacks, and repeats the number to an operator in the distant office. The second operator then completes the connection by plugging into the called subscriber's jack with a cord which is attached to the incoming trunk. The upper half of Figure 1 shows diagrammatically just how these steps are performed.

Now the dial system is quite similar, in principle at least, to this sytem in which human operators make the connections. As far as the subscriber is concerned, the only difference is that he calls numbers with his finger instead of with his larynx. The dial on his telephone is simply a form of switch, by means of which he gives orders to the robot operator. When he dials the number "3," for instance, the circuit through his telephone is interrupted three times in quick succession, and electrical impulses are thereby sent to apparatus in the central office.

Here we come to the really fascinating part of an automatic telephone system: the central office machinery which, with almost human intelligence, executes the dial-given commands of ten thousand subscribers. It will be easier to understand how this apparatus works if we stop to consider just what functions an automatic central office must fulfill.

Primarily, of course, the office must contain selecting equipment, flexible enough to link any sub-



Comparison between the Manual and the Panel Dial telephone systems.

scriber's line to any of ten thousand similar lines within the office, or to any of several hundred trunks leading to other offices. This selecting apparatus is the most fundamental requirement of all. It would be possible to operate a telephone system with practically nothing else in the central office, providing every subscriber's line were furnished with a selector.

This mechanism is very expensive, however, and is used by each subscriber's line for only a small part of the time; it would be foolish, therefore, to provide selecting apparatus for every telephone in town. Instead, methods have been worked out whereby, say, fifteen hundred selecting channels can serve ten thousand subscribers; and since fifteen hundred people in one office area are almost never telephoning at the same time, there are plenty of channels to go around.

But now the problem arises of furnishing a subscriber with a selector when he needs one, since none is permanently allotted to his line. The solution of this problem is a very flexible form of selecting mechanism, known as a "line finder." As soon as a subscriber lifts his receiver off the hook, this piece of apparatus connects his line to an idle selecting channel, thus allowing him to dial his call.

So far, everything we have been saying applies to *any* kind of automatic telephone system. Without selectors of some kind, no machine-switching scheme could work at all; and without line finders, none could be practical except on a very small scale.

In this country, the general practice is to provide what is known as the "panel" system in densely populated metropolitan areas, while in cities or areas of somewhat less size the so-called "step-by-step" system is used. In the latter system electromagnets, actuated directly by dial impulses, operate the selectors; that is, every time a subscriber's dial clicks, one of the selector switches advances a step. A typical step-by-step outfit is installed in the Massachusetts Institute of Technology Electrical Engineering Department.

The panel system is used in metropolitan areas because of its greater capacity and adaptability to multi-office conditions. In this system, just as in a step-by-step installation, line finders and selectors make up a large part of the equipment. Their mechanical design, however, is radically different from that of "step" apparatus. For example, the driving power for the selectors in a panel office is furnished by continuously running motors instead of electromagnets.

In order to secure the required flexibility and control of these motor-driven selectors, a most remarkable piece of apparatus known as a "sender" has been devised. This is located between the line-finder and the selecting-channel equipment.

The sender, together with an associated piece of equipment known as a "decoder," acts primarily as a kind of director. It takes orders from the subscriber's dial, translates these into appropriate dispatching signals, and controls the successive steps of selection until the called line is finally reached. The sender and decoder must therefore be not only a director, but a linguist as well, translating the commands of the dial into language that the selectors can understand.

Now the sender is required only during the first few seconds of a call, while the selectors are locating the called subscriber's line. Its work is all done before the subscribers even begin to talk. Consequently, a relatively few senders are sufficient to control a much larger number of selecting channels, if only each sender can be readily shifted from one channel to another. This flexibility is provided by a switching device known as a "sender selector," whose function is to pick out and assign a sender whenever a selecting channel needs one.

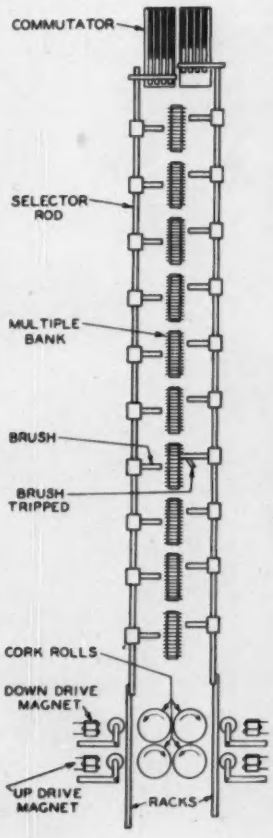
Summarizing the foregoing, we see that the panel dial system contains four kinds of equipment, which operate in about the following order:

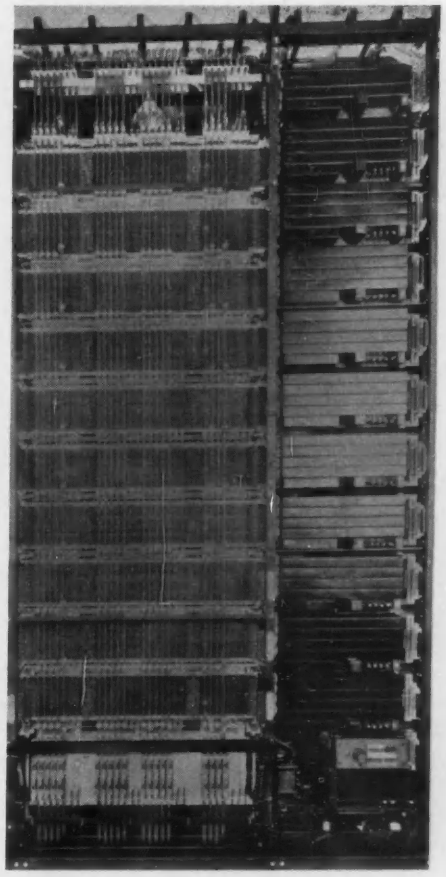
1. The line finder, which connects the calling subscriber to an idle selecting channel.
2. The sender selector, which assigns an idle sender to this selecting channel.
3. The sender itself, which takes down the dial's orders, translates them into a different language, reissues them to the selectors, and controls the call through to its destination.
4. The selecting apparatus, which performs the progressive operations through the local and distant offices, finally picking out the called subscriber's number and completing the connection.

Figure 1 shows how these successive steps are related to each other, and to the corresponding stages of the manual system. For simplicity the sender selector has been omitted from the figure; if it were included, it would appear just above the sender.

We note from the diagram that selection of the called subscriber's line is not accomplished all in one step; instead, it occurs in three distinct stages. First of all, a selector on the "district frame" picks out a trunk leading to the correct central office. The next selection is made in the distant office, on its "incoming frame";

(*Continued on page 40*)





What a line-finder frame looks like. At left, a diagrammatic end view; at right, a photograph of the frame as seen from the front.

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EDITORIALS

TO THE PUBLIC

MOST residents of the Boston Metropolitan area look upon Massachusetts Institute of Technology as an imposing group of buildings that furnishes an impressive sight when lighted up at night. Few of them have anything but vague conceptions of the work carried on within the granite walls that constitute its exterior. It is for such persons that Massachusetts Institute of Technology holds its annual Open House, which will be conducted this year on May 6.

To the average layman, the sight of machinery whirring and laboratories in operation holds a deep interest. Spectacular experiments, unusual demonstrations of a technical nature, and attractive exhibits provide for him a real entertainment. None of these features will be missing when the Institute opens its doors in May to show Mr. Public that science and engineering are not so forbidding as some textbooks might make him believe.

Two years will have passed since the last Open House, when tens of thousands availed themselves of the opportunity of visiting Massachusetts Institute of Technology. Since then, two additions have been made to the Institute's plant which the public will be enabled to see for the first time. These are the Eastman Research laboratories and the nearby Spectroscopy Laboratory, both of which should prove of especial interest. As before, all of the laboratories and shops will be in regular operation.

May is not so far off as it seems, and it is not too early to extend invitations for this event, one of the too rare occasions when laymen can see some of the latest developments in research and technical education.

UNDERGRADUATE ACTIVITIES

COLLEGE years may be considered from two points of view, either one of which leads to the same conclusion as regards activities: i.e., that when properly administered, they are of great value to those participating in them.

If one considers college as four years of preparation for life, it must be remembered that while technical knowledge is certainly a factor in obtaining success, it is by no means the only one, or even so large a one as is popularly imagined. The qualities of leadership, coöperation, group-spirit, etc., which bulk so large later in life, are all fostered by undergraduate activities.

From the other side of the fence, college is a part of life itself. How then can a man isolated from extra-curricular activities expect to succeed in a position in which a certain amount of trust and responsibility is his, if such a position is suddenly thrust upon him after four years of neglect of those qualities of leadership which activities develop?

Freshmen and sophomores, if they but look around, will find plenty of opportunities for activity connections at Technology. It would be worth their while to take that look.

INTERNATIONAL BOYCOTT

RECENTLY the United States declared that it was in "moral agreement" with the League of Nations when the latter decided to boycott Japan. There is no doubt as to how this measure will affect Japan, but how will it affect the United States? Japan is the third largest consumer of our national exports. If we lose

this valuable market, how many men will join the vast ranks of the unemployed, how much harder will the government have to strive to keep everyone clothed and fed, how much higher will the taxes be raised to meet the added expense? Perhaps it is better to sympathize with the League in their actions rather than to actually coöperate with them in their embargo

But if we continue to trade with Japan and supply her with the necessary munitions for the maintenance of her invading army — what then? The League will be revealed as a failure, Japan will probably capture all of China, and the resulting strain on international relations may even lead to another world war.

Well, why not try the boycott? The only thing against it seems to be the uncertainty of its result and the loss of trade. If, however, all nations do put an embargo on Japan, the war will soon be over, the Chinese will once again go back to their fields, the embargo will be lifted, and trade will be resumed with a renewed vigor. In conclusion, it seems that the United States should coöperate unreservedly with the League of Nations to bring peace to the Far East, even though it may mean the temporary loss of a much-needed market.

REAL SCIENCE

THE dilettante is commencing to superficially examine science just as he has examined economics — with the lamentable results which are apparent in national prejudices and word-of-mouth political dribble. Now, with news of energy surveys, of depression, and of an ever-growing machine environment looming in the tabloids, men are looking ambitiously at science and engineering; how tempting are these rare intellectual dishes!

In view of these dangers, engineers and scientists, by emphasizing the fact that mathematics and experiment are the real stuff of science, might well discourage those who spread such practices. For example, what could be a more effective means of convincing the unqualified talker of his error than an exposure to the Calculus?

EDUCATIONAL POLICIES

THE student at Technology is faced with a system which appears to be both complete and efficient. All the doors in the Institute have numbers and names identifying, in a general way, what goes on behind them. The telephone system is more than sufficient; a fine mimeographing service is always available; photostats and photographs can be obtained at a reasonable rate. But this high degree of organization is in some cases extremely superficial.

Let us consider the question, "What are the educational policies of the Institute?" In one subject, the student finds that his grade is figured relatively to the others in his class; in another subject, he finds a set standard of work which each man must do in order to receive a passing grade. Are we wrong in considering this matter a fundamental policy which should be decided by the Administration and not left to the discretion of each individual instructor?

In many courses the sections are so divided that there are about twenty to thirty men in each of the sections. This policy is followed in so many cases that it would appear to be favored by the Administration. Why, then, was there no division made in a course where there were approximately one hundred and fifty students, many of whom complained that they could not follow the instructor?

Has the Institute definite educational policies? We wonder.

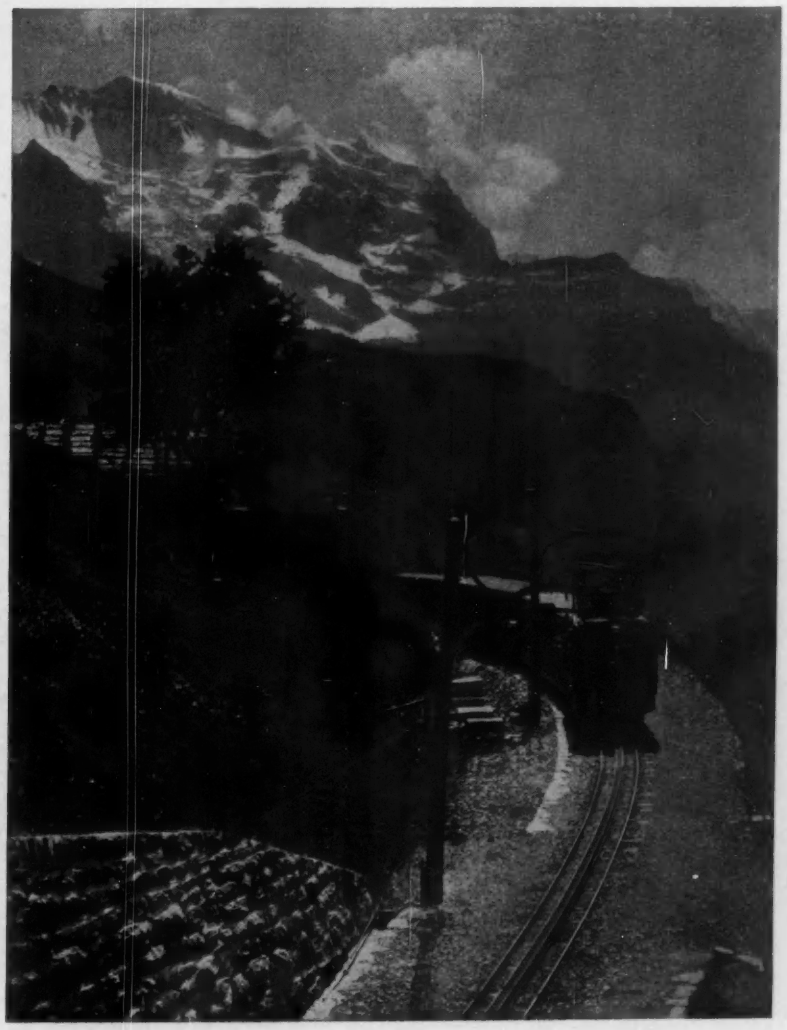
HOUSE CLEANING

THE famous old theory of the survival of the fittest has manifested itself quite strikingly in the current economic situation. Large business enterprises which could well afford to keep employees who were not especially well fitted for their positions did so rather than follow the distasteful procedure of dismissing them. After the 1929 crisis, however, a change occurred. Men who were "dead wood" were the first to lose their positions and with them were the new men who had not met up with the expectations of those who had hired them. In the final analysis, industry has sponsored an old-fashioned Spring House Cleaning.

Of course, the Massachusetts Institute of Technology is not exactly a business enterprise; but it is a corporation and Spring is not very far off.

ANNOUNCEMENT

THE Managing Board takes pleasure in announcing the election of Gordon K. Burns '34 to the position of Managing Editor to fill the vacancy created by the withdrawal of Warren Bubier.



Electric power on the Wengernalp Railway, in Switzerland.

ENGINEERING DIGEST

Condensation of outstanding articles in the trade and scientific journals, published by special permission

HIGH FLYING

Scientific American, *March, 1933*

HIGH altitudes known as the stratosphere will, in all probability, be the region in which airplanes of the near future will fly. One reason for this prophecy is the fact that in the high altitudes there exist strata of air where there are no "bumps"; another is that at the higher altitudes the air density is less, resulting in less air resistance and consequently greater speed of travel.

The weather in the stratosphere is calm compared with that at sea level, where squalls and sudden atmospheric changes endanger flying and result in inconvenience and perhaps loss of time and money to passengers through failure of the planes to maintain flying schedule. The air in the stratosphere always flows in a smooth manner and in a horizontal direction; furthermore, these winds decrease in intensity as the altitude is increased. Although there still remain some uncertainties about the velocities and directions of air currents in the stratosphere, these are gradually being cleared up by flights like those of Professor Piccard.

At present, really long flights are not made because with the motors and planes now in use, not enough fuel and other supplies can be carried for long flights if many passengers are to be carried. With high-altitude planes these difficulties can, partially at least, be overcome. Since air is a very compressible fluid, its density and, therefore, its resistance decrease as the altitude is increased. This may be illustrated by the fact that at sea level thirteen cubic feet of air weighs one pound whereas at an altitude of fifty thousand feet, eighty-six cubic feet of air weighs only one pound. This fact is the reason why engineers are turning their thoughts to high-speed flying for the future, and are even considering rocket ships which, it is estimated, may reach altitudes of as much as one hundred thousand feet.

However, the matter of designing, building and operating planes for use in the stratosphere is not an easy task, for the advantages of smoother riding and faster service are counterbalanced by a number of disadvantages. People who are used to living in the denser air on the surface of the earth experience "altitude sickness" when they reach great heights. This sickness starts with laboring of the heart, and is usually followed by headaches and often unconsciousness. A successful passenger plane service must provide means of preventing, or at least alleviating, such sickness.

Severe drops in temperature are also encountered at high altitudes; at an altitude of fifty thousand feet the temperature is about seventy degrees below zero Fahrenheit. This intense cold is at present counteracted by the use of fur-lined gloves and clothing which are sometimes electrically heated, but satisfactory passenger service would require that the cabin be electrically heated so that the passengers may wear their normal clothing.

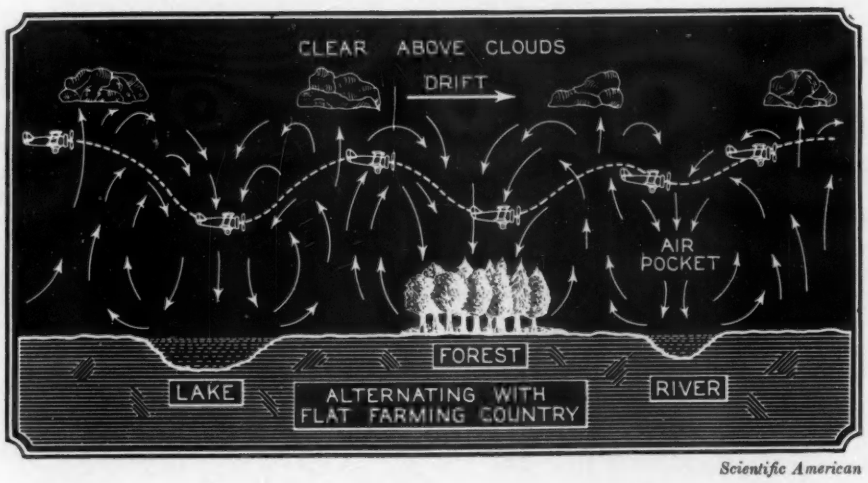
The airplane engine, like the passengers, requires as much air at higher altitudes as it does on the ground. To provide this air in the rarified atmosphere, superchargers are installed on all planes designed for flying at high altitudes. If such precautionary measures were not taken, the power would fall off alarmingly as the plane reached great heights.

SHIFTING CONTINENTS

Science, *February 3, 1933*

THAT the distance between the United States and England varies sixty-three feet each day as the moon moves across the sky is the hypothesis advanced to the American Astronomical Society by Dr. H. T. Stetson, director of the Perkins Observatory at Delaware, Ohio, and A. L. Loomis, of the Loomis Laboratory, Tuxedo Park, New York.

With what is probably the most complete installation of precision clocks and automatic radio sets in the world, Loomis has recorded the time signals from a number of national observatories and has found surprising variations in American and British time. The time is determined in both places by observing the instant that a star crosses the meridian. If, therefore, two observatories are shifting slightly in longitude, the star will cross the more western meridian slightly early when the western observatory is slightly east of its average position, and slightly late when the observatory is west of its average position relative to the more eastern observatory. In the absence of any other satisfactory explanation, Loomis and Stetson have put forward their hypothesis which attempts to explain the variation in step with the moon's position, by attributing the observed variations of time to a natural stretching or shifting of the earth's crust, which, under the gravitational attraction of the moon, periodically yields and recovers a distance which is estimated at about sixty-three feet.



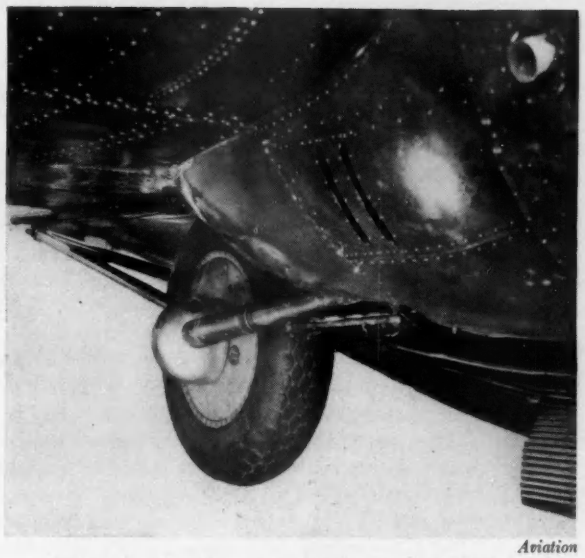
Scientific American

At low altitudes "air pockets," caused by irregularities in the earth's terrain, make flying "bumpy."

RADIO SPECTRUM

Proc. Institute of Radio Engineers, *February, 1933*

FOR the past decade the problem of providing both rural and urban broadcast listeners with at least one continuous program of high quality has been taxing the ability of radio engineers. The technical difficulties would not be insurmountable if broadcasting were the only service to consider. However, the spectrum available for broad-



Aviation

How the landing gear looks during flight. Compare with photograph below.

cast purposes is very limited, and any radical change in the frequency assignments of other radio services which might be made to accommodate more broadcast stations would render much existing equipment obsolete. In consequence, solutions of the problem to date have merely been economic compromises rather than the result of a well planned system from the engineering point of view.

In Europe as well as in America the problem of providing the maximum number of useful broadcast channels has been met by separating geographically as far as possible two stations operating on the same or on adjacent "channels" and by assigning to stations in the same geographical location, carrier frequencies so widely separated that the possibility of interference with modern transmitters and receivers is, in most cases, negligible. In the United States, governmental regulations require that the frequency of the broadcast station deviate from its assigned value by less than fifty cycles per second in order to reduce to a minimum one source of interference.

Now the useful selectivity and frequency separation of broadcast stations depends not only upon the type of transmitting and receiving equipment employed, but also on the power of the transmitter and on the characteristics of the human ear. With proper consideration given to all of these factors, under favorable conditions a few additional high quality programs could be maintained in the present broadcast frequency band by "sandwiching them in" between existing programs. Additional programs could also be provided by extending the present broadcast band and operating more stations. In the first case the number of additional programs which could be accommodated would not be very great and would require the whole-hearted coöperation of existing stations, a matter of more difficulty in Europe than in America. The second proposal, that of increasing the size of the broadcast band, may be justified in Europe where for some time two broadcast bands have been in actual use. In this country, however, such a program appears to be economically inexpedient, so that it seems unlikely that any extensions in the present broadcast band will be made in the immediate future.

Apparently good broadcast service for both rural and urban listeners cannot be expected so long as the present system of assigning broadcast frequencies is continued. In the future, best service will probably be obtained by providing a true radio system for rural communities and a wire distribution system providing a choice of programs for densely populated areas.

DISAPPEARING WHEELS

Aviation, *February, 1933*

Modern business is crying for speed and aviation is finding ways and means to supply this demand. Designers are making every attempt to eliminate sources of air resistance and have concentrated their attack in recent years upon the landing gear. A most important part of an airplane while on the ground, the landing gear becomes a parasite when in the air — especially so since today's high-speed ships are "cleaner," and the drag of the landing gear is a greater proportion of the total retarding force than it used to be. Consequently, the increase in speed gained by the use of a retracted landing gear is now sufficient to warrant the additional complication.

The danger of the landing gear not being in the proper position at the time of landing cannot be overlooked. This condition might result from one or more of four causes: a structural failure of a landing gear part or the actuating mechanism, because of faulty design, materials, or workmanship; fouling of the wheel bracing linkage, or actuating mechanism, by ice or mud; pilot's neglect to lower the wheels, which can be eliminated by proper warning devices; and the slowness of the mechanism in the event of a forced landing.

In the interests of safety, manufacturers are compelled by Department of Commerce regulations to see that all these possible causes of failure are rendered highly improbable. Many interesting warning devices to combat the human-error element in the pilot have been developed. They are for the most part electrical mechanisms and are actuated if the throttle is retarded when the wheels are not locked in the down position. Lights, a horn near the pilot's ear, and even an electric motor with an eccentric weight which causes the control stick to vibrate are examples. As far as can be determined, however, there has been no instance of a personal injury as a result of a retractable landing gear functioning improperly.

This system of reducing air resistance appeals to the airlines, of course, for it permits increased speed and lower fuel consumption for a given flight distance.

Aviation

Here the plane is on the ground, with its wheels extended.

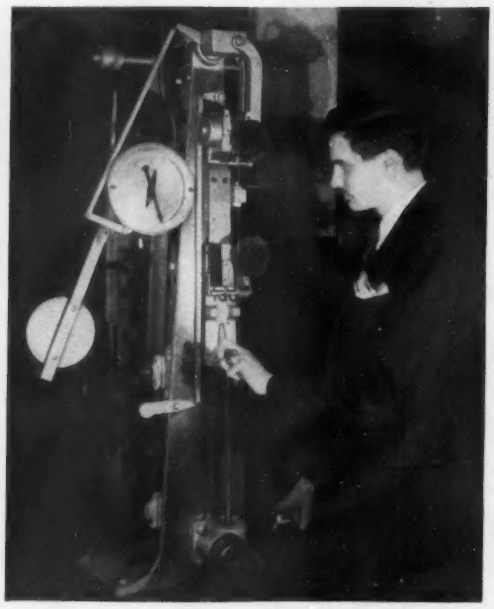
RESEARCH IN REVIEW

COURSE II
Mechanical Engineering

In order to study microscopically the surfaces of textile fibers without the obscuring interference of the details of their internal structure, workers in the textile microscopy laboratory of the Department of Mechanical Engineering have prepared transparent casts of the fibers. The structure of the surface is considered one of the most important properties of a textile fiber, and a more thorough examination of this property is being undertaken by the investigators, who are working under a fellowship grant from the Textile Foundation.

These casts, which eliminate all internal structure that would be objectionable, present numerous problems in their preparation. Although each fiber is only a few hundred-thousandths of an inch in diameter, the cast must retain all the minute details of contour that are present on the fiber. The task is thus a delicate one.

Since all textile fibers are largely microscopic, the department has been endeavoring to examine them with every possible variation of microscopic technique. Polarized light is being used to investigate the textiles, correlating with work already under way at Massachusetts Institute of Technology and at other institutions on the X-ray analysis of the fibers' ultimate structure. In this connection, direct color photomicrography is being utilized.



Bell Laboratories Record

Accurate measurements are essential in modern research.

COURSE VII
Biology and Public Health

Electricity is being utilized in three projects under way by members of the research staff in the Department of Biology and Public Health. These consist of a photo-electric bacteria counter, an electrolytic purifier of enzymes, and a device to carry on electrophoresis experiments in the study of the fundamental nature of bacteria.

The "bacteriometer," devised by Dr. M. W. Jennison, was on exhibition in December at the convention of the American Association for the Advancement of Science in Atlantic City. A test tube containing a bacteria culture intercepts a beam of light which impinges upon a photo-electric cell. The current emitted from the cell is inversely proportional to the number of bacteria; and this number may be read on a properly calibrated ammeter. This measurement is accurate to within 2 per cent, while common bacteriological methods only afford an accuracy of 5 per cent.

The purity of enzymes such as peptones, protein solutions, and albumins is an important factor in their biological utility. The apparatus developed in the department to purify these enzymes by electrolysis makes use of the difference in size between enzyme and impurity. Salts and protein derivatives easily pass through the pores of a collodion membrane surrounding each electrode, but the pepsin molecules are too large and remain in solution.

It has been known for a long time that bacteria are negatively charged, and when placed in an electric field are attracted to the positive electrode. This phenomenon is known as electrophoresis. In the Institute's biological laboratories it is being utilized as a physical method for studying the fundamental properties of cells and for obtaining information about their structure. Velocities of certain bacteria in a solution of low conductivity have been measured.

COURSE XII
Geology

The conclusions reached in a study of glittering mica schists and many granites in New England will be presented in a paper soon to be published by Professor Morris of the Institute's Department of Geology and by Professor Larsen of Harvard. By showing that the direction of thrust has almost no relation to the directions of the growth of the minerals, they refute the older view that compression of the rocks caused minerals to recrystallize as long, flat crystals, arranged with their longest axes at right angles to the direction of thrust. According to the paper the rocks were recrystallized and partly replaced by hot, uprising solutions coming from underlying masses of molten, igneous magma.

COURSE XIV
Electrochemical Engineering

Two papers on the results of research conducted in the Electrochemical Laboratory will be presented at the Montreal meeting of the Electrochemical Society in May. One of these is on "The Electrical Conductivity of Solutions of Water in Sulphur Dioxide," by Prof. M. DeKay Thompson and C. F. Jelen. The other, a study of chromium plating on zinc from the point of view of protection, was Mr. Jelen's master's thesis.

Manufacturers of sulphur dioxide who hoped that conductivity would furnish a rapid means of detecting water in the dioxide will perhaps be disappointed in the conclusions reached by the investigators into the first subject. The conductivity was determined as a function of the water content from the gas's dehydrated state to its saturation. No appreciable increase in conductivity was found between the dehydrated dioxide and that containing thirty parts per million of water. Between these two concentrations lies the range in which moisture must be determined commercially. It was found that the conductivity changes rapidly from aqueous contents of 100, to those of 1,000, parts per million.

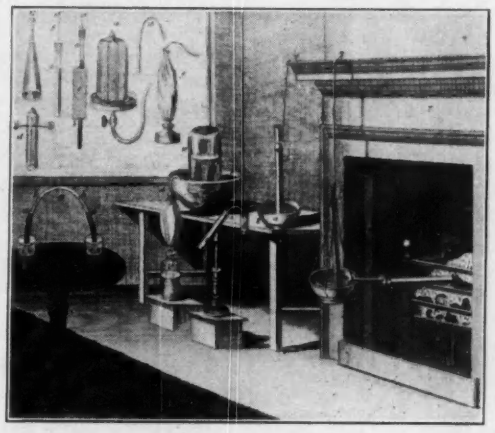
The article about "Chromium Plating on Zinc" discusses a series of tests to determine under what conditions the plating would have the longest life when immersed in corrosive solutions. Most suitable was found a composite plate over the zinc of equal thicknesses of copper and nickel as a base for the chromium.

This proved to be two to three times as efficient as a deposit of nickel alone.

JOSEPH PRIESTLEY

(*Continued from page 24*)

Benjamin Rush, Thomas Cooper, John Maclean, and David Rittenhouse. Not a single American chemist of the time accepted the outmoded phlogiston doctrine which Priestley defended to the last, but they all gave respectful attention to his views and were encouraged to experiment for themselves. Priestley continued his controversy with the "French school of antiphlogistic chemists" and published several pamphlets in defence of the older doctrine which his own discoveries were largely instrumental in overthrowing. There are passages in these pamphlets which are caustic; there are many which are witty; there are some which are wistful. It is clear that chemistry after all was his secondary interest, that his primary interest was theology. The second edition of "The Doctrine of Phlogiston Established, and That of the Composition of Water Refuted" (dated Northumberland, 1803, but actually printed after the author's death) contains a letter addressed to the French chemists, which ends as follows:



Journal of Chemical Education

Priestley's Laboratory

"On the opening of this controversy I told Mr. Adet* that I should have greater pride in acknowledging myself convinced, if I saw reason to be, than in victory, and should surrender my arms with pleasure. I was sincere in that declaration; and certainly the conquest of a man's prejudice is more honourable to him than the discovery, or the most successful defence, of any truth. This, however, I must, for the present at least, decline, and leave it to you; contenting myself with the inferior praise of confirming the hypothesis for which I have contended. If, from the politeness habitual to Frenchmen, you should decline this honour, thinking my claim to it better founded than yours, I may hereafter be induced to receive it; but for the present, yielding to you a palm more glorious than that of any victory, and trusting that your political revolution will be more stable than this chemical one, I am, with the greatest respect, Gentlemen, Your Fellow-citizen, Joseph Priestley."

The preface of the same work contains a very clear statement of Priestley's state of mind with reference to the phlogiston controversy.

"The refutation of a fallacious hypothesis, especially one that is so fundamental as this, cannot but be of great importance to the future progress of science. It is like taking down a false light which misleads the mariner, and removing a great obstacle in the path of knowledge. The longer such a hypothesis has been received, and the more numerous and able are its advocates, the greater service is rendered to science by the refutation. And there is not perhaps any example of a philosophical hypothesis, since the revival of true science, more generally received, or maintained by persons of greater eminence, than this of the rejection of *phlogiston*.

"But my philosophical friends must excuse me if, without neglecting natural science, I give a decided preference to theological studies, and if here, as in Europe, I give the greatest part of my time to *them*. They are unquestionably of unspeakably more importance to men, as being designed for immortality. . . . No discovery in philosophy bears any proportion in real value to that of *bringing life and immortality to light*, which is completely effected in the Gospel, and nowhere else. . . .

"Call this, if you please, the talkativeness of age; but believe it to proceed from a zeal in the best of causes, and sincere good will to yourselves. For I find that I have insensibly got into a direct address in the form of a *dedication*, rather than that of a *Preface*. With this, however, I conclude. Farewell, and may we meet where our present doubts will be removed, and where we shall make more rapid advances in knowledge, without that envy and jealousy, from which philosophers are no more exempt than other men, and which, though it has an excellent effect in making men cautious, and even ardent in their pursuits, with a view to the reputation they hope to acquire by their discoveries, too often makes their pursuits the source of more pain than pleasure to them. Hereafter, we shall, I doubt not, be even more actively employed, and more happy in consequence of it, from better motives."

The closing sentence of the Preface of Priestley's lost pamphlet proved to be prophetic.

"I am truly thankful to the sovereign disposer of all things, and to those friends of science who have defrayed the expenses of my laboratory, that I have been able to do so much; and I hope my liberal benefactors will not repent their generosity."

* Adet was Ambassador of France to the United States. He had been one of the group which coöperated with Lavoisier in devising and publishing a new chemical nomenclature.

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UNITED HOTELS

OXIDATION

(*Continued from page 25*)

require manual stimulation, which do receive more lay attention even though they may not be any more adequately appreciated. These processes usually force themselves on the attention by virtue of their distressing results. The causes of comfort, well-being, and gain do not require attention, and by the average person are taken for granted; whereas the causes of discomfort, distress, and economic loss demand attention and get it. It should be of interest to examine some of these undesirable actions of oxygen.

In the early days of the automobile it was not uncommon for the rubber tires to become hard and full of cracks — virtually useless — before they were destroyed by actual wear. The same thing was likely to happen to almost any rubber article exposed to sun and air. Or perhaps the effect was the opposite and the article became soft, sticky, and equally worthless. Oxygen had been at work and had reacted with the rubber to form a new and useless compound. The same oxygen could act in the same way today, and when, improperly vulcanized, rubber is left exposed to strong sun and hot air, it does. But, through the use of "antitoxants," the rubber chemist has been able to prolong greatly the economic life of rubber goods by materially lessening the rate at which the oxygen attacks. The results are not perfect, the protection not complete, and chemists are constantly working with new substances in an effort to find a more effective antitoxant.

Corrosion of the ferrous metals represents a tremendous economic loss. The magnitude of this loss is estimated with difficulty and any figures are approximate only. Hedges estimates this loss to be on the order of two and a half million dollars per year for the world. Surely the enormity of such a loss could not pass without notice. It has not, and much money and energy has been expended in an effort to decrease it. Indeed, great as the losses are at present, they are much less than they would have been if manufacturers and research organizations had not given considerable attention to the causes of corrosion and studied means for its prevention during the past twenty-five or thirty years.

The development of the electrochemical theory of corrosion by W. R. Whitney, W. H. Walker, and others in the Research Laboratory of Applied Chemistry during the early years of this century did much to pave the way for the formulation of methods designed to prevent and alleviate the troubles. Deterioration of metal parts exposed to atmospheric or submerged corrosion is most often prevented by preventing access of the "elements" to the surface. Three different types of protective surface are used: organic — paints, varnishes, lacquers, greases, tars, etc.; metals — tin plate, zinc galvanizing, and chromium, cadmium, or nickel electrodeposits; chemical — anodically deposited oxide films on aluminum, Parkerized deposits on steel, etc. Certain alloys, such as "stainless iron and steel," are capable of building up very thin, invisible films of corrosion products which protect against the continued attack of oxygen and moisture, and are finding increased use. So-called corrosion "inhibitors" or pickeling "inhibitors" are useful in combating corrosion in ferrous metal systems where aqueous solutions are continually recirculated or are used for a time before being discarded. An example of such an application is in the use of sodium or potassium dichromate in the "freezing" brines used in refrigerating or quick-freeze plants.

The development of means for controlling the action of oxygen and oxygen-rich substances on chemical compounds has put a powerful tool into the hands of the chemical industry. Although Priestley's announcement of the identification of oxygen was not made until 1774, and although oxidation reactions on the whole were not given systematic attention until late in the nineteenth century, there exists today a chemical industry which turns out an imposing number of chemical substances in large bulk, many of which have felt the effect of oxygen as a chemical reagent.

The development of the controlled oxidation of nitrogen enabled Germany to produce nitrates and nitric acid during the World War on a scale that would have been out of the question by the arc process of direct nitrogen oxidation.

The human desire for color in personal adornment, in household furnishings, in articles of food, etc., has created a large and insistent demand for dyestuffs. Up to about the middle of the nineteenth century certain plants and insects were depended upon exclusively as sources for these colors: Chemists, led by Perkin, Graebe, Liebermann, Baeyer, and other pioneers, working in the latter half of the nineteenth century, laid the foundations of a great synthetic dye industry by developing methods of synthesis which made the same colors available at much lower cost. The natural dyes were not only rapidly supplanted by the new synthetic colors, but they were also surpassed in variety and quality. Today literally thousands of dyestuffs are available. Many of these depend directly upon the action of oxygen either for their raw materials, for their color, or for their application to fabrics.

Processes of oxidation have been extensively investigated in an attempt to make some chemical use of the enormous quantities of low molecular weight paraffin hydrocarbons available in natural gas, refinery gas, coke oven gas, etc. Thus, if a single atom of oxygen could be introduced into a molecule of methane, CH_4, a molecule of methanol, CH_4O, would result, and a cheap gas would be converted into a valuable liquid solvent. The same is true for the few next higher members of the same series. It is estimated that could this be accomplished, with theoretical conversion, approxi-

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mately 22,000,000,000 gallons of methanol, 5,800,000,000 gallons of ethanol, and 2,600,000,000 gallons of propanol would become available yearly. While such figures are preposterous, they emphasize the colossal amounts of these cheap raw materials now either used as fuel or largely wasted.

Experiments have shown that the introduction of a single oxygen atom into a molecule of these hydrocarbons can be accomplished only with difficulty. They have also shown that a more far-reaching reaction, *i.e.*, the formation of an aldehyde, is easier of accomplishment. However, the ease of accomplishment of even this latter step is not such as to make the process of present economic importance. Nevertheless, the possibilities are so alluring and the promised reward so great that effort will continue to be expended in an attempt to solve the baffling problem.

Results of more immediate promise have been obtained by the oxidation of the liquid hydrocarbons of petroleum oils, and it is interesting to conjecture upon the use of petroleum as a raw material. Already much progress has been made, and solvents, fatty acids, soaps, new detergents, new lubricants, etc., are appearing on the market.

A rather interesting application of controlled oxidation is in the coloring of aluminum articles. Articles to be colored are electrolytically oxidized and then treated with aniline dyes. A beautifully colored, hard, lustrous finish, that is virtually part of the metal, results.

This article could be continued almost without end, so numerous and varied are the encounters of man with oxygen, but enough has been said to furnish an introduction for anyone not already familiar with the variety of its effects.

ASTRONOMY

(*Continued from page 27*)

giant in the constellation Scorpio, has a diameter of close to 400 million miles; Arcturus, an orange giant, a diameter of 30 million miles, and there are like results for some five additional stars. If one remembers that the sun's diameter is about 865,000 miles, and that it is a yellow star of the dwarf branch, it is apparent that our fairy story of giants and dwarfs is close to the truth.

As a matter of fact the absolute magnitude of a star may be expressed as a function of the temperature and radius of the star. This relation is not rigorous, but it is a very good approximation. If then the absolute magnitude and temperature of a star are known, a close approximation to its radius may be derived. Of particular interest in this connection are the white stars of very low absolute magnitude that are labelled white dwarfs. Despite their high temperature, they remain exceedingly faint and hence must be very small; computation by the method just outlined makes them planetary in size. It is to be noted that they are relatively rare objects.

The determination of the masses of stars can be accomplished only by a study of the gravitational interactions of pairs of stars, where the two members of the pair are constrained to pursue observable orbits about their common center of gravity. From the study of these double stars it is found that the masses of stars to all intents are nearly the same despite their great difference of size. As a result the great range in size of the stars must lead to a tremendous variation in density. One finds that the average density of the red giants is less than the most perfect man-made vacuum, that the average density of the stars on the giant branch gradually increases as one progresses toward the hotter stars and continues to increase along the dwarf branch in the direction of the cooler stars. The sun's average density is 1.5 times that of water, that of a red dwarf about that of iron, and that of the white dwarfs of the order of a few tons to the cubic inch, unbelievable but possible.

The most important step in our expanding knowledge of the scale of the universe came from the discovery of a group of variable stars known as Cepheid variables. Here is a class of stars the apparent magnitudes of whose members do not remain constant but fluctuate continually and rhythmically with perfectly determined periods. It is thought most likely that this variation in brightness results from a rhythmic pulsation of the star with its accompanying change in size and temperature. But most important is the fact that the period of variation of a Cepheid is the immediate key to its average absolute magnitude. They are all super-giants, those with periods less than a day being white stars with absolute magnitude close to 0, while with increasing periods the Cepheids fall further and further back along the giant branch of the diagram, the Cepheid with the longest period, about 70 days, being an orange star with an absolute magnitude of about −3.5. So, find a Cepheid, observe its period, and you immediately have its absolute magnitude and thence its distance. Fortunately Cepheids are quite ubiquitous and when one finds in a distinct stellar system a Cepheid of 40 days period and apparent magnitude 20, it becomes immediately apparent that that object is not exactly a next door neighbor of ours. The computed distance for such a Cepheid is about 500,000 light-years. Indeed it is these stars that have furnished the stepping stones in our rapidly expanding knowledge of the size of the universe. For, from the distances of certain classes of stellar systems determined in this fashion has come the discovery of new modes of attack that lead us ever outwards into the measurable depths of space.

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DIAL TELEPHONE

(*Continued from page 31*)

this choice narrows the field down to five hundred subscribers. Last in the series comes the "final frame," where the correct individual line is picked out. In very large metropolitan areas, the system is often expanded by inserting another set of selectors — known as "office frames" — in the series, immediately after the district frames.

With this general view of the panel system in mind, let us take a little closer look at the mechanical construction of some of its equipment. We shall have to skip over a good deal, including details of the sender. It would take much more space than we have available, to explain how this clever machine fulfills the combined duties of interpreter, card-file clerk and dispatcher.

Line-finder and selector frames, on the other hand, are relatively simple; furthermore, these two types of apparatus are mechanically very much alike, so that in describing either of them we shall cover the other fairly well. Let us then consider, say, a line-finder frame.

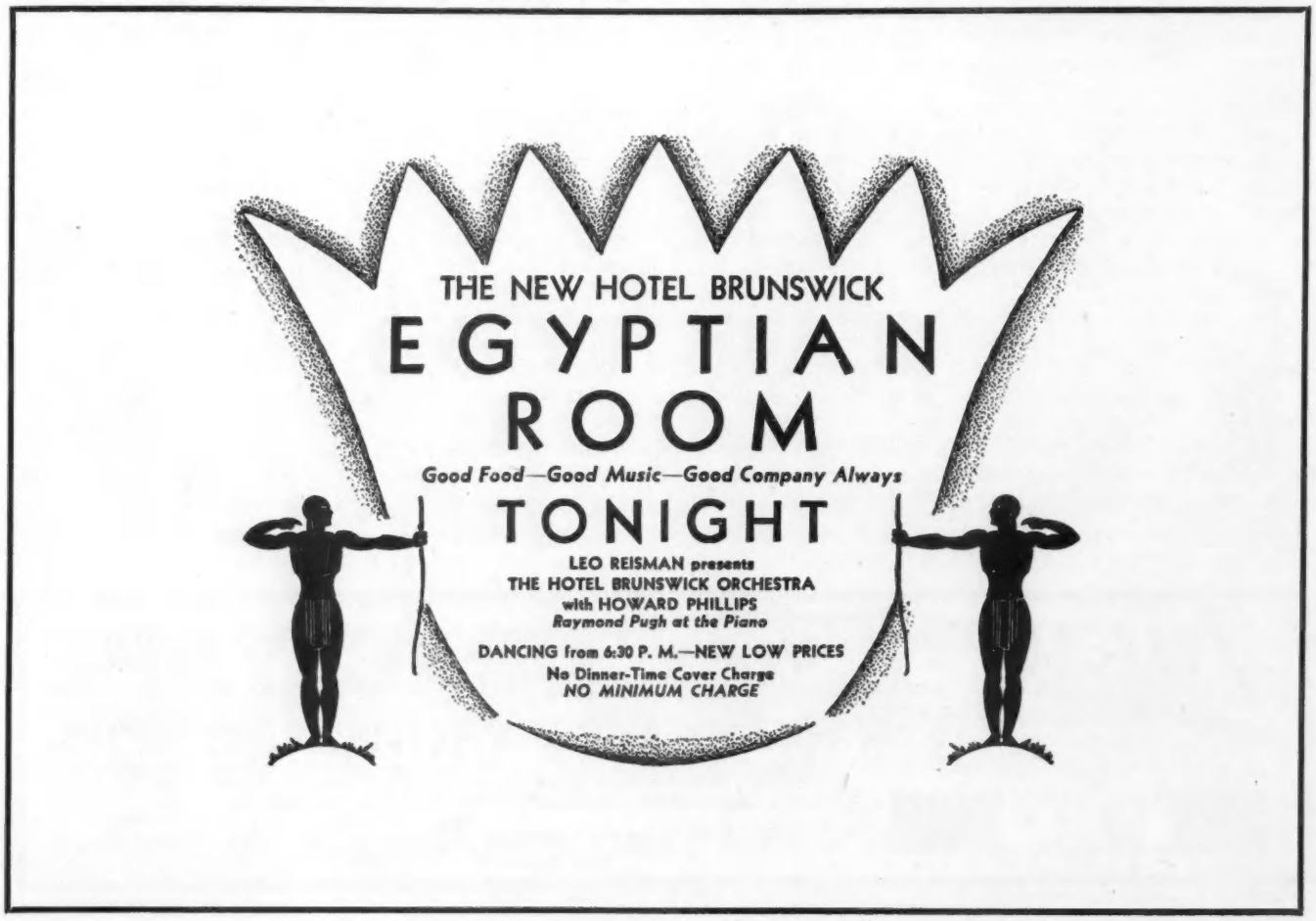
The object of this mechanism, we recall, is to serve as a link between calling subscribers and idle selecting channels. To achieve this purpose, each subscriber's line is brought in to a set of stationary terminals. Each selecting channel is connected to a movable brush which can make contact with any of these sets of terminals. Thus, in a given frame, any selecting channel which happens to be idle can be connected to any subscriber's line.

As Figure 2 shows, the stationary terminals are grouped in vertical "multiple banks" or panels. Each bank is built up of flat horizontal strips of metal, running the full width of the bank and separated by layers of insulation. Each subscriber's line is connected to a group of four strips: forty such groups constitute a bank, and ten banks are included on a frame. The edges of the metal strips are toothed at intervals with projecting lugs, which protrude from the bank and form the stationary contacts.

The movable brushes which wipe over these lugs are mounted on vertical "selector rods." Connections from the brushes to apparatus located elsewhere in the office are made through commutators, one of which is provided at the top of each rod. The selector rods, under the control of magnetic clutches, are carried up and down by means of motor-driven cork rolls. Now, as Figure 2 reveals, there are ten brushes on each rod. When the rod is idle, all the brushes are held in a non-operative position. When the selector is in use, however, any one of the ten can be brought into contact with its bank by means of a tripping mechanism.

Observe what happens when a subscriber lifts his receiver from the hook: a clutch engages and one of the idle rods climbs upward, with the proper brush tripped. As soon as this brush comes to the subscriber's line, the clutch disengages and the selector halts, being prevented from falling back by a pawl. At the end of the call the down-drive clutch is energized, the pawl is released, and the selector returns to its idle position.

It must be understood that the foregoing is only a very sketchy outline of how just one piece of apparatus works. Nevertheless, it will serve to give some idea of the way in which panel equipment functions. When we remember that a typical office in a large city may contain hundreds of line-finder and selector frames, every one going through these same operations day in and day out, we begin to sense the real magnitude of the panel dial system.



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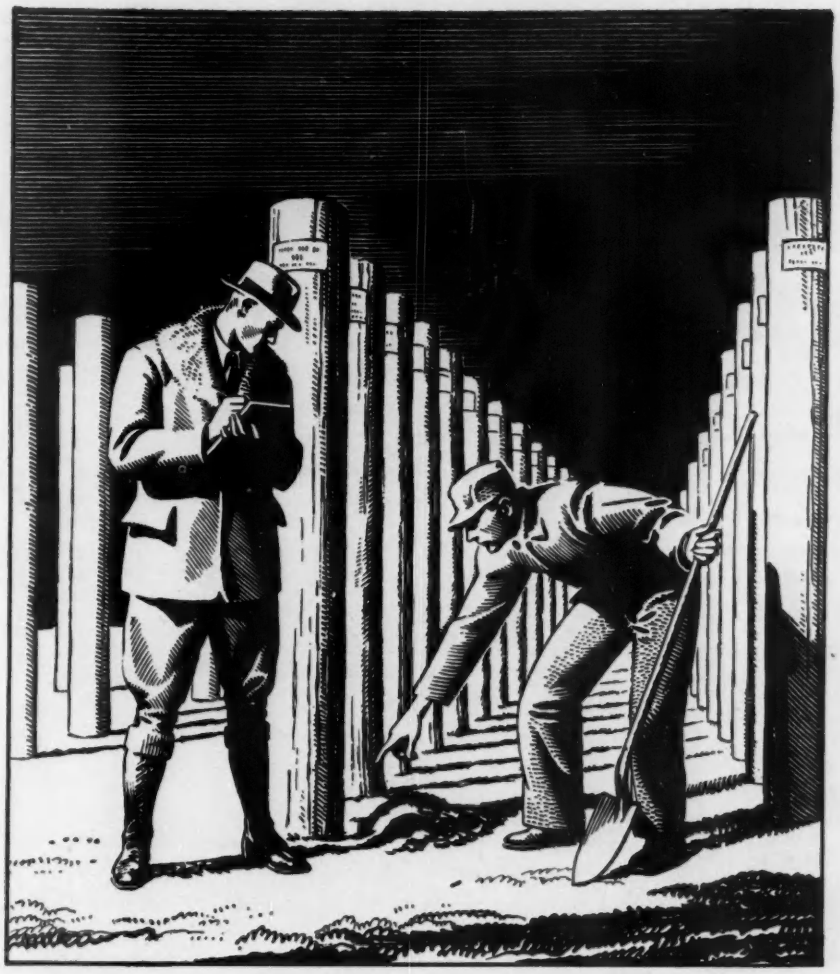

Wooden soldiers
in the war *against decay*

To conquer the forces of decay which attack telephone poles, scientists of Bell Telephone Laboratories carry on a relentless campaign.

They study many kinds of wood, test many preservatives. They isolate wood destroying fungi and insects—study them in the laboratory—search for a practical means of combating their attack. They have set out armies of stub poles in Mississippi, Colorado and New Jersey where altitude, climate and soil vary widely. At regular intervals they inspect these poles to learn which woods and preservatives are best.

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G-E *Campus News*

TAMING LIGHTNING

A crackle, a deafening crash—and a gigantic streak of man-generated lightning leaped 30 feet. Thus, was 10,000,000 volts, the largest artificial flash ever produced by man, discharged at the G-E high-voltage laboratory.

To produce this enormous voltage, a 50,000,000-kw. lightning generator imitates nature. Hundreds of small capacitors take the place of nature's clouds. They are charged by transformers. When the voltage is built up, the capacitors are discharged in series to produce 10,000,000 volts. Sounds simple, doesn't it? However, the power output of the generator—during the infinitesimal period of the flash—is nearly twice that of all the generating stations in the United States.

F. W. Peek, Jr., a Stanford grad of '05, was chiefly responsible for this achievement—incidentally, he is now the chief engineer of the G-E Pittsfield Works. "Lightning tamer," his old classmates would probably call him. And rightly proud of him they should be, for in the field of transients and dielectric phenomena he is second to no one.

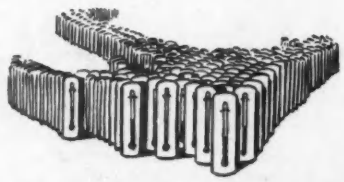
ATOM CHASER

On December 10th last, a mild-mannered scientist stood in the Great Hall in Stockholm and received the Nobel Award in Chemistry for 1932. Then he went skiing with his wife and daughter, seemingly unmoved by being the second American chemist in 31 years to be so honored.

In 1909 Dr. Irving Langmuir, a '03 graduate of Columbia University, came to Schenectady, to the G-E Research Laboratory, to ask questions about tungsten wire, its behavior in a vacuum. He stayed, just "looking around" and wondering why the bulbs of incandescent lamps blackened so easily. He found out, and thus developed the gas-filled lamp. It saves Americans a million dollars every night.

Then he wondered about atoms cooperating with electrons and produced the high-vacuum electronic tube, making possible radio broadcasting, which created an industry. Incidentally, he contributed a new type of welding—atomic-hydrogen.

They call him atom chaser, electron driver. The Swedish Academy of Science rewarded him — not for lamps, radio tubes, or welding methods, but for achievements in pure science. For just "wondering."



25 MILLION THERMOMETERS

You may have heard about our new power plant at Schenectady—the first of its kind ever built. In it there's a 20,000-kw. mercury-vapor turbine. The plant uses mercury vapor for power, the exhaust vapor producing superheated steam.

270,000 pounds of mercury will be needed for the boilers. That's enough for 25,000,000 thermometers. Perhaps you wonder why we don't use water. Well, the new process makes possible some thirty per cent more power from coal than heretofore. And we don't expect that those boilers will be refilled.

W. L. R. Emmet, an '81 graduate of the U. S. Naval Academy, is the inventor of this mercury-vapor process. That isn't all he's done, either. In his capacity as a consulting engineer at G. E., he developed the steam turbine from a small beginning to a place of dominating importance, and he first applied electric power to ship propulsion.

FLAME WITHOUT SMOKE

Smoke and soot mean wasted energy. That's what our engineers thought, too. They rolled up their sleeves and began to work. For five years they studied electric control of oil combustion. And they developed progressive impact combustion; they broke a single drop of furnace oil into a hundred million parts.

In this process, oil and air collide under pressure, and each drop of oil breaks up into millions of particles. Application of heat further breaks down the oil into gaseous hydrocarbons; and when the latter encounter air, the entire energy of the fuel is converted into hot flame without loss of carbon in smoke.

This is just one of the features of the radically different G-E oil furnace — another G-E achievement. And such men as E. D. Harrington, a '16 grad of Beloit College, helped to chuck tradition to the winds. He was closely associated with the entire development of the oil furnace. He's now Engineer of the new Air Conditioning Department.

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GENERAL ELECTRIC